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(71) Applicant(s)

Honda Giken Kogyo Kabushiki Kaisha

(Incorporated in Japan)

1-1 Minami-Aoyama 2-chome, Minato-ku, Tokyo 107,
Japan

(72) Inventor(s)

Hiroyuki Horimura

Tadahiro Kubota

Toyoahi Baba

Kazuya Takahashi

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(74) Agent and/or Address for Service

Frank B Dehn & Co
Imperial House, 15-19 Kingsway, LONDON,
WC2B 6UZ, United Kingdom

(54) High strength amorphous aluminum-based alloy and process for producing amorphous aluminum-based alloy structural member

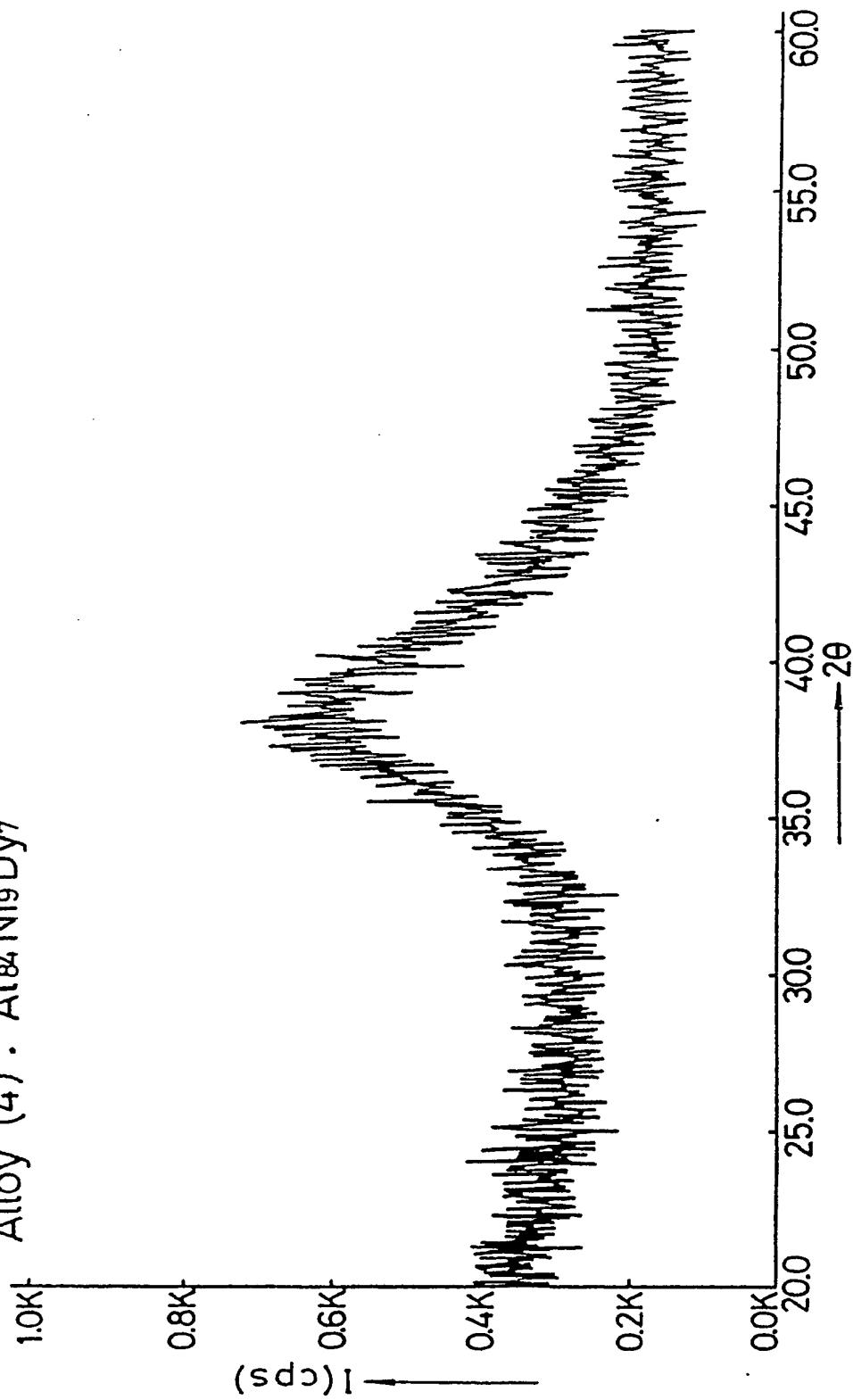
(57) A structural member is produced from an amorphous aluminium alloy by compacting at a temperature at least 40°C below the crystallization temperature to form a green compact of at least 80% density. The amorphous aluminum-based alloy may comprise 75 atom % (inclusive) to 90 atom % (inclusive) of Al; 3 atom % (inclusive) to 15 atom % (inclusive) of Ni; and 3 atom % (inclusive) to 12 atom % (inclusive) of at least one element selected from the group consisting of Dy, Er and Gd, and has an amorphous layer volume fraction (Vf) of at least 50%.

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FIG.1

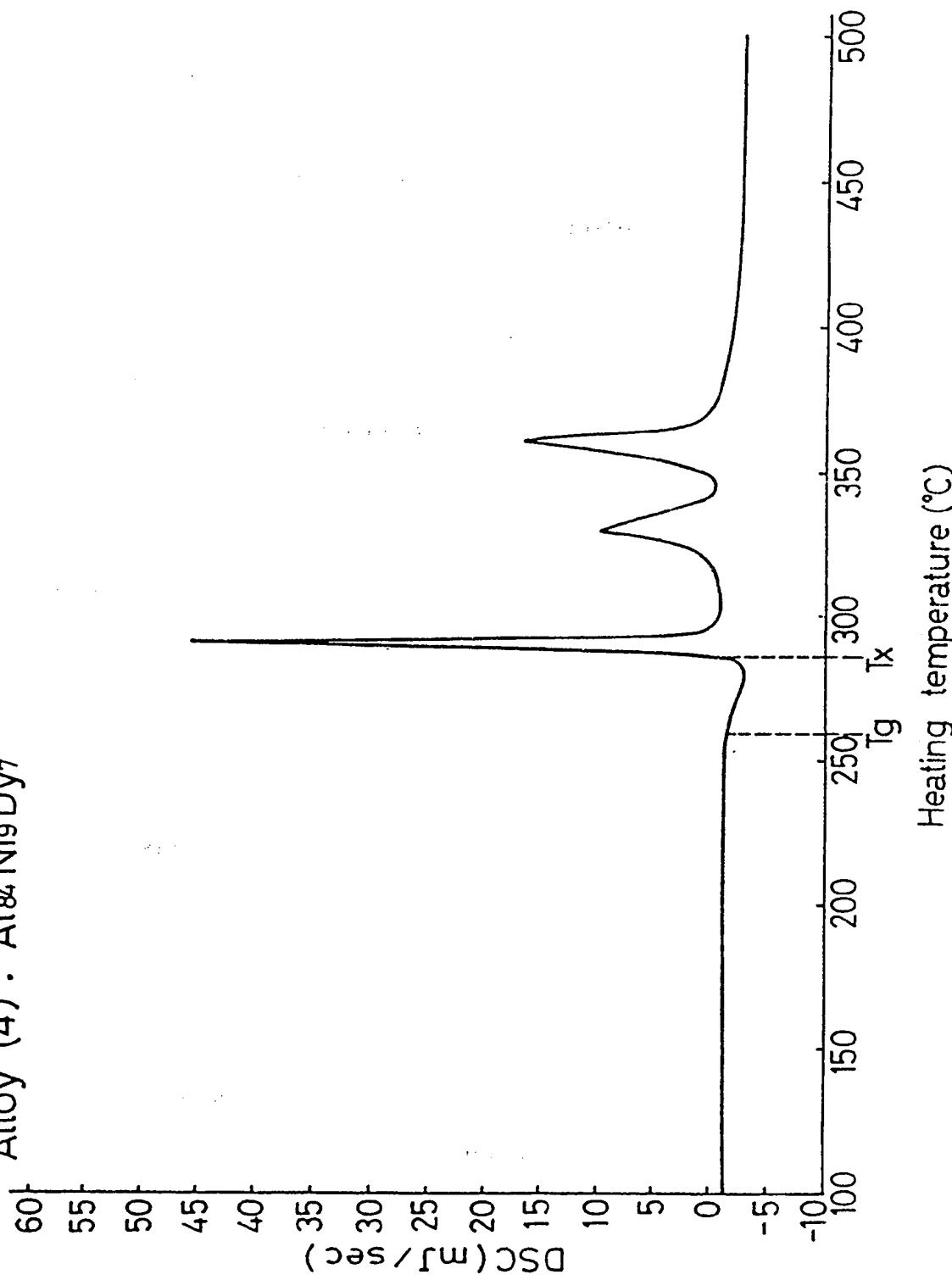
Alloy (4) : $\text{Al}_{84}\text{Ni}_{9}\text{Dy}_7$



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FIG.2

Alloy (4) : $\text{Al}_{84}\text{Ni}_9\text{Dy}_7$



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FIG.3

Alloy (6) : $\text{Al}_{84}\text{Ni}_{10}\text{Dy}_6$

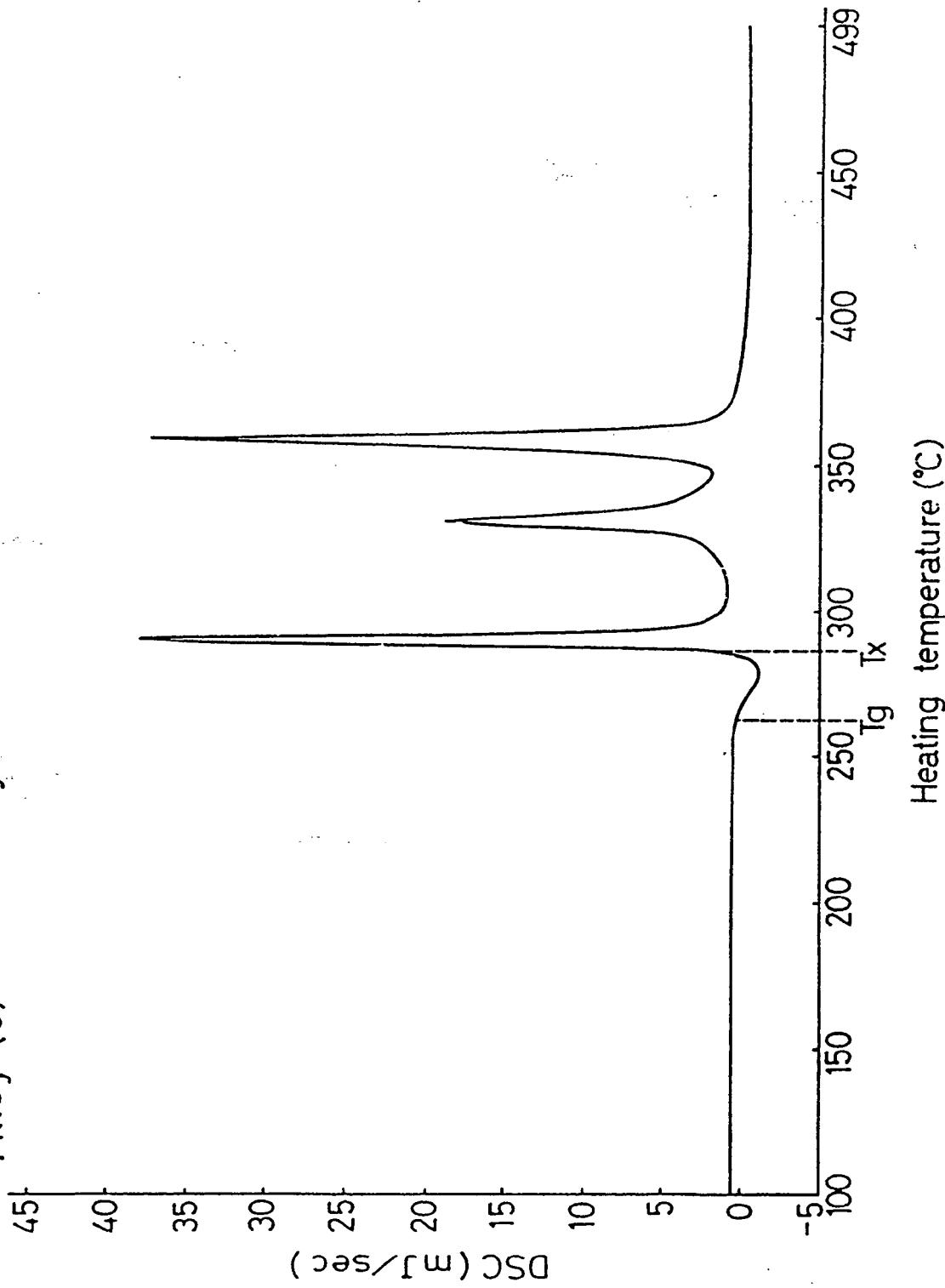
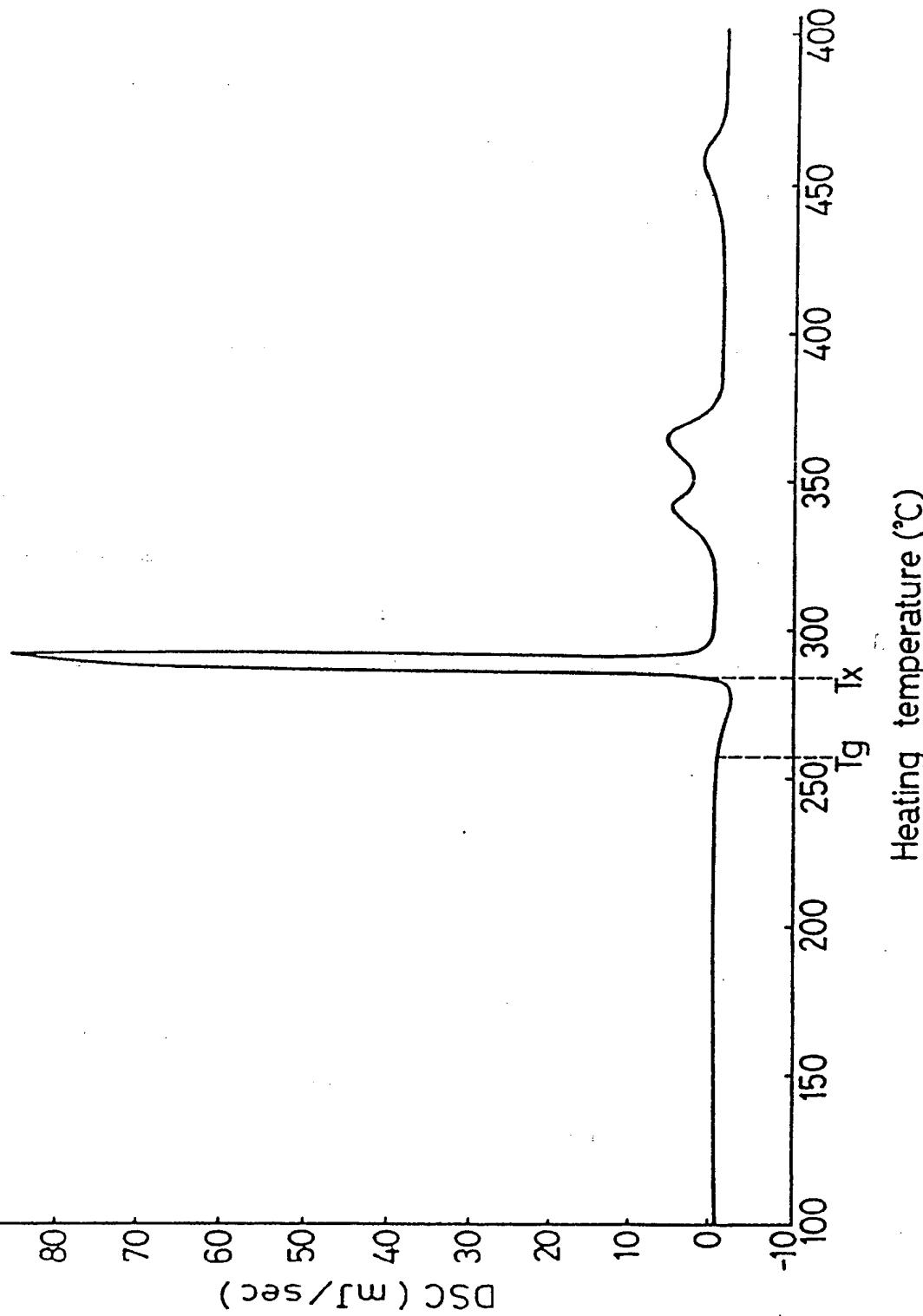


FIG.4

Alloy (11) : $Al_{84}Ni_{10}Dy_3Mn_3$



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FIG.5

Alloy (12) : $Al_{84}Ni_{10}Dy_2Md_4$

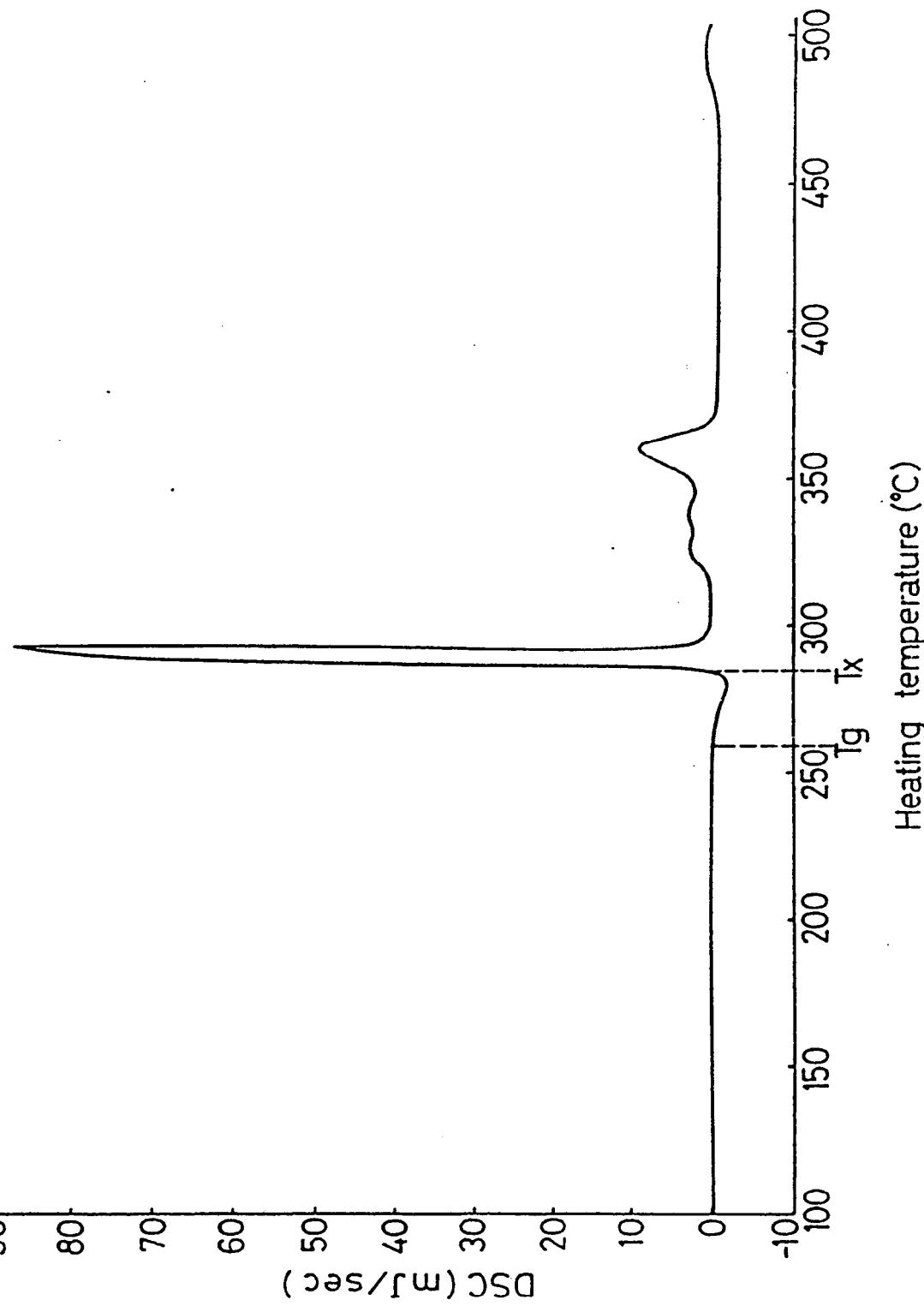
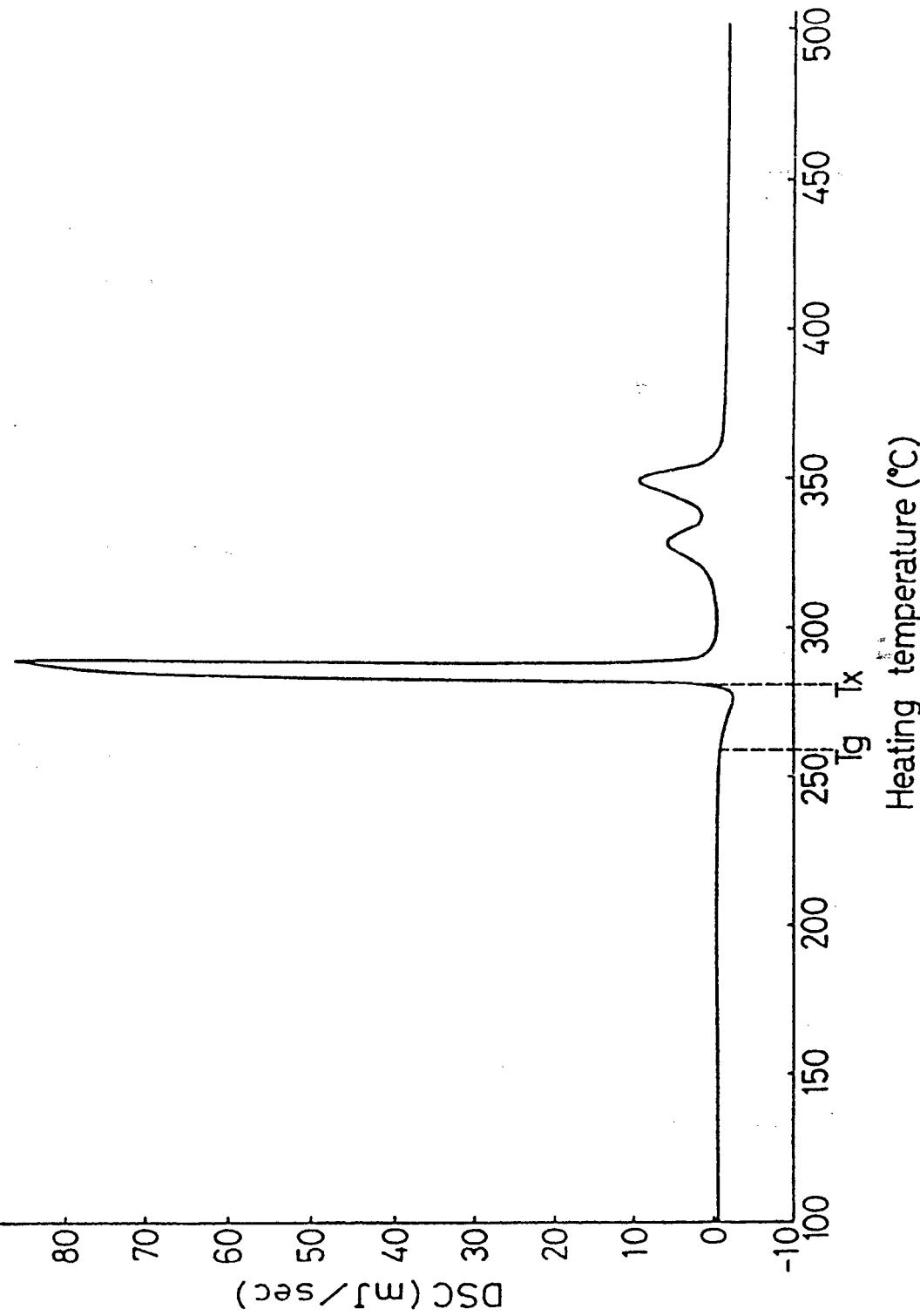


FIG.6

Alloy (13) : $\text{Al}_{84}\text{Ni}_{10}\text{Dy}_1\text{Mn}_5$



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FIG.7

Alloy (14) : $Al_{84}Ni_{10}Er_3Md_3$

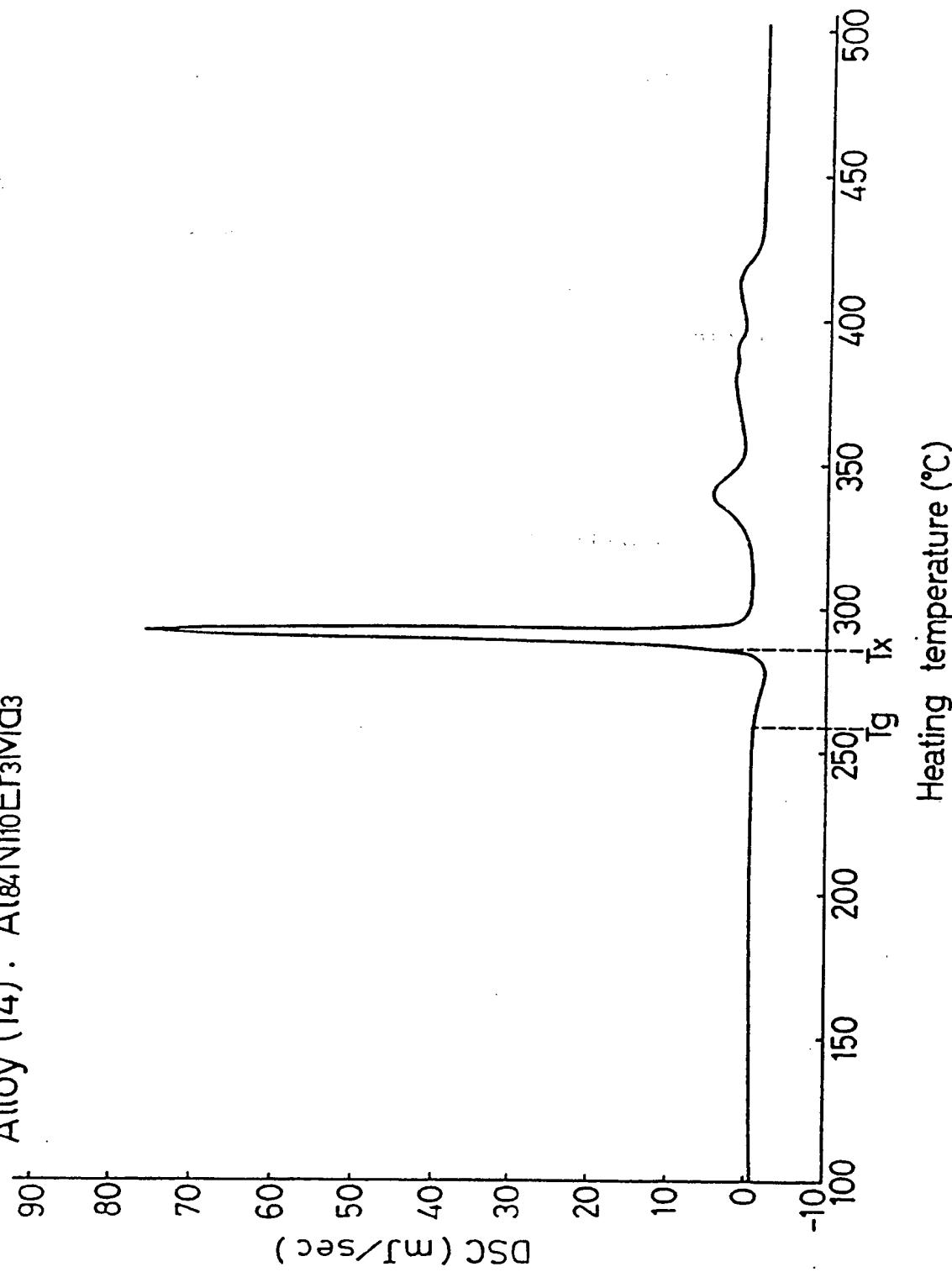


FIG.8

Alloy (31) : $\text{Al}_{85}\text{Ni}_{8}\text{Dy}_{8}\text{Co}_2$

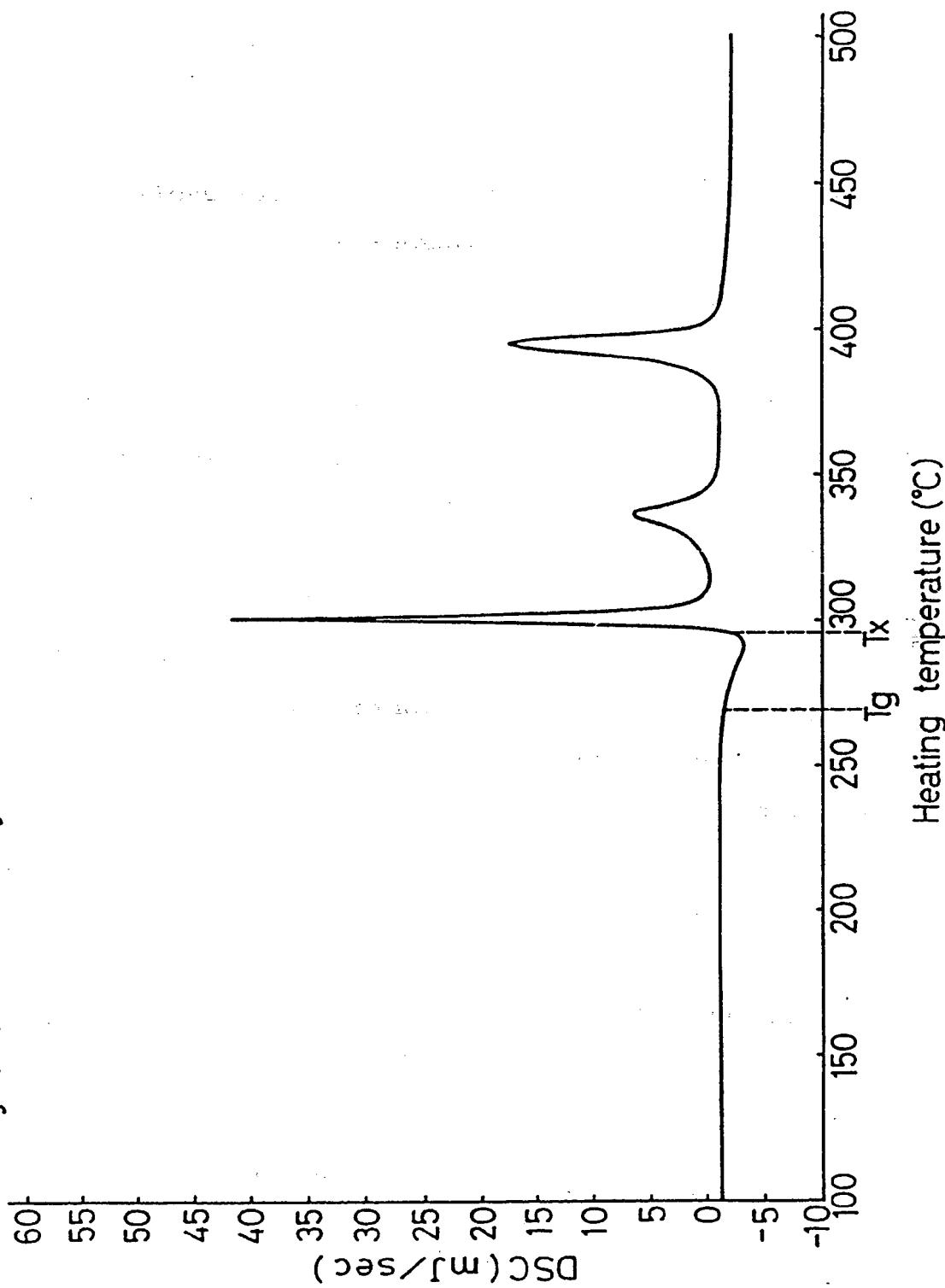


FIG.9

Alloy (34): Al₈₄Ni₈Dy₃Mn₃Co₂

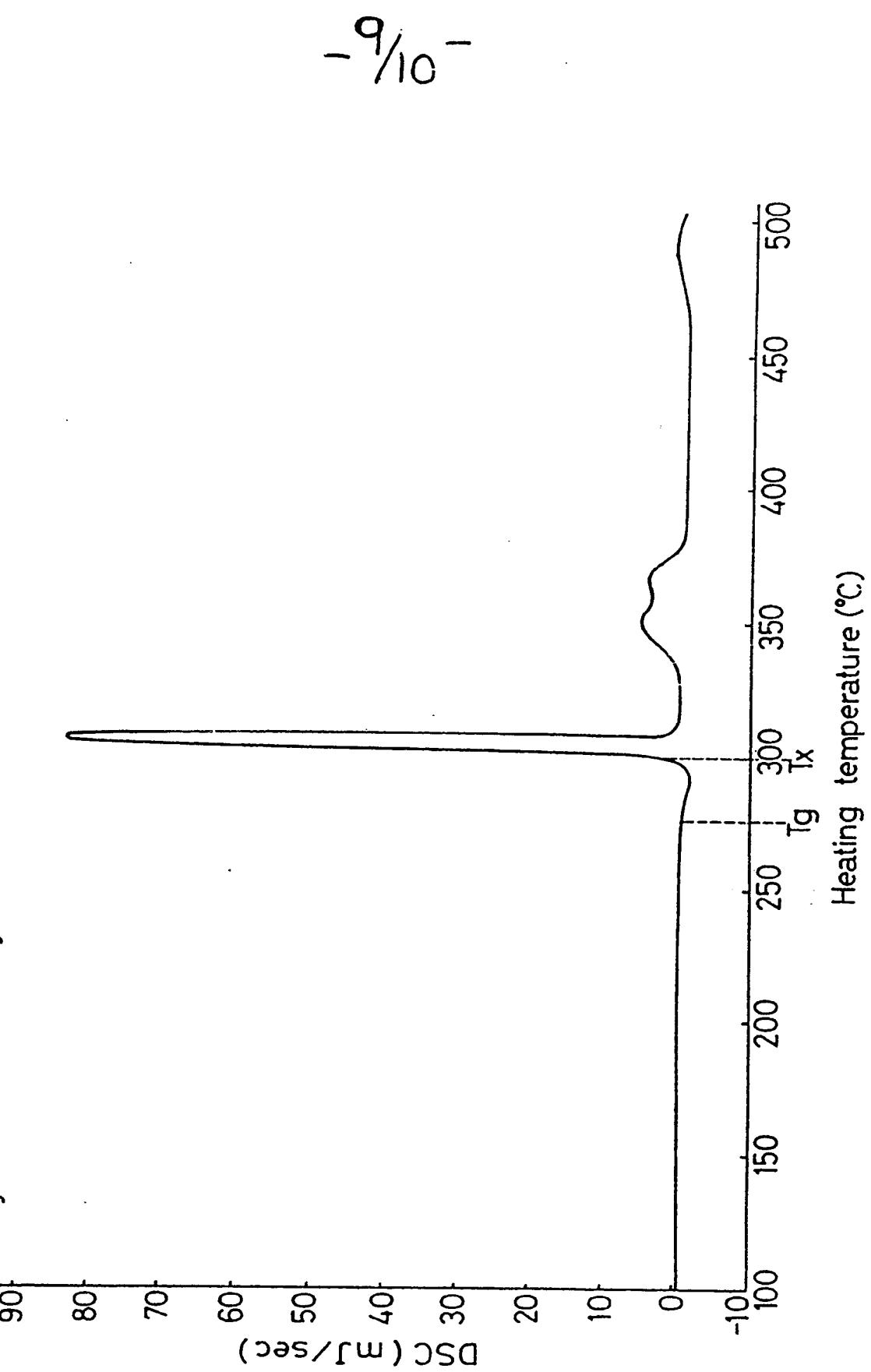
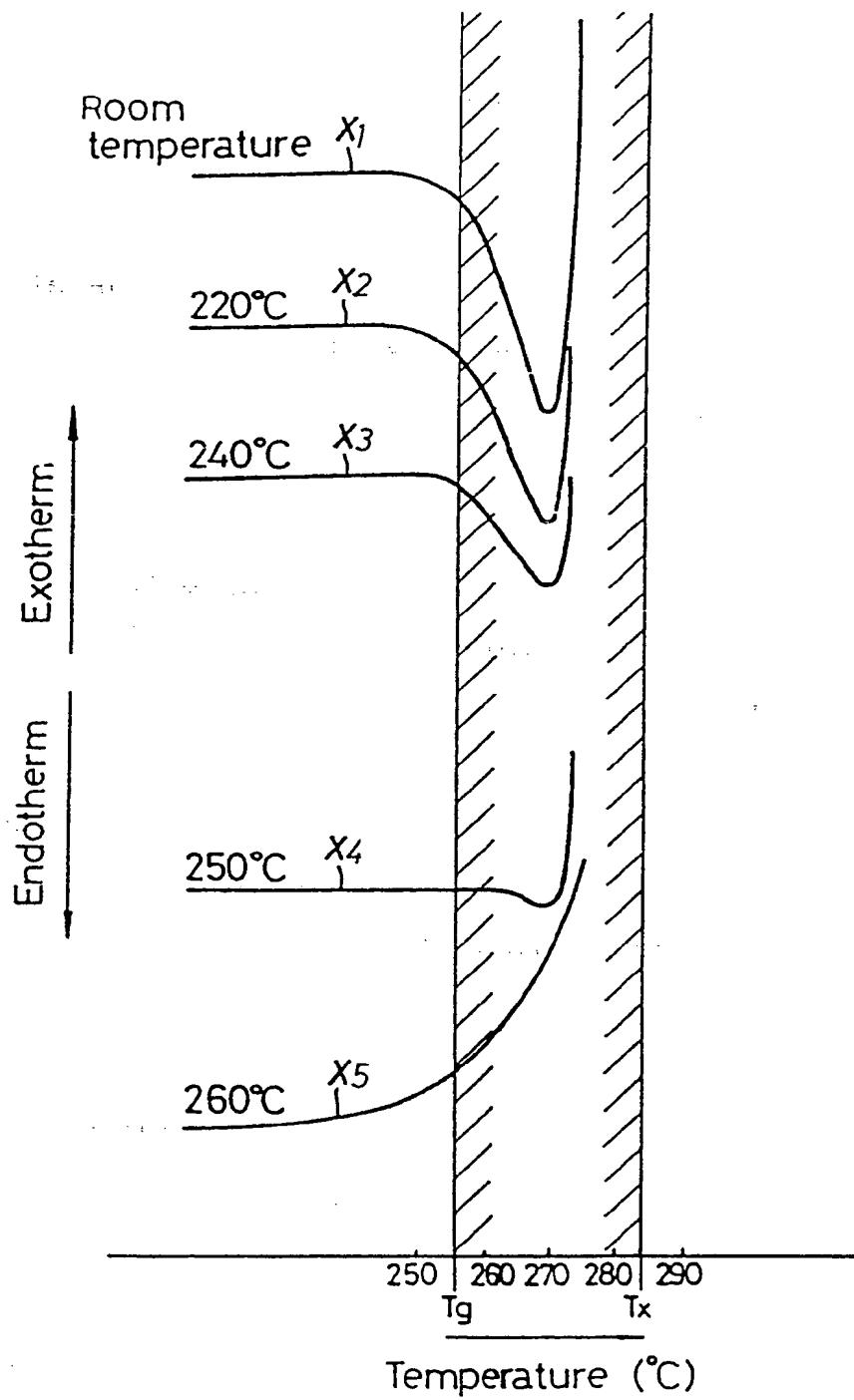


FIG.10



HIGH STRENGTH AMORPHOUS ALUMINUM-BASED ALLOY
AND PROCESS FOR PRODUCING AMORPHOUS ALUMINUM-BASED
ALLOY STRUCTURAL MEMBER

The field of the present invention is high strength amorphous aluminum-based alloys and processes for producing an amorphous aluminum-based alloy structural member using the same.

There are numerous known amorphous-aluminum-based alloys comprising various transition elements added to Al.

However, the conventional amorphous aluminum-based alloys suffer from a problem that the amorphous substance forming ability in production thereof is relatively lower. Another problem associated with such conventional alloys is that in producing a member using such alloys, the workability thereof is inferior, because a plastically workable temperature region between the glass transition temperature (Tg) and the crystallization temperature (Tx) is relatively narrow.

There is also a conventionally known process for producing a structural member of an amorphous aluminum-based alloy, which comprises forming a green compact from an amorphous aluminum-based alloy powder having a amorphous layer volume fraction (Vf) of 50% or more and subjecting the green

compact to a hot plastic working. In this producing process, the density of the green compact is set relatively low.

When the density of the green compact is relatively low, however, the following problem is encountered: In a hot plastic working at the next step, e.g., in a hot extrusion, a relatively large slip may occur between the alloy powder particles forming the green compact, thereby causing the temperature of the alloy powder to be increased due to the attendant friction and deformation, with the result that the crystallization advances to provide a reduction in volume fraction of amorphous layer in the resulting structural member.

It is an object of the present invention to provide an alloy of the type described above, which has a higher amorphous substance-forming ability and a wider plastically workable temperature region.

To achieve the above object, there is provided a high strength amorphous aluminum-based alloy comprising 75 atom % (inclusive) to 90 atom % (inclusive) of Al; 3 atom % (inclusive) to 15 atom % (inclusive) of Ni; 3 atom % (inclusive) to 12 atom % (inclusive) of at least one selected from the group consisting of Dy, Er and Gd, and having an amorphous layer volume fraction (Vf) of at least 50%.

In addition, according to the present invention, there is provided a high strength amorphous aluminum-based alloy comprising 1 atom % (inclusive) to 12 atom % of at least one selected from the group consisting of Dy, Er and Gd; and 8

atom % or less of at least one selected from the group consisting of La, Ce, Pr, Nd and Md (misch metal).

Further, according to the present invention, there is provided a high strength amorphous aluminum-based alloy comprising at least one selected from the group consisting of Co and Fe, and Ni in a total amount of 3 atom % (inclusive) to 15 atom % (inclusive) in place of Ni added alone.

If the contents of Al, Ni and at least one selected from the group consisting of Dy, Er and Gd are specified as described above, the amorphous layer forming ability can be enhanced. Therefore, it is possible to produce a high strength amorphous aluminum-based alloy having a volume fraction (Vf) of amorphous layer of 50% or more by utilizing an industrial producing process such as a gas atomizing process and the like. Such a alloy has an advantage of a wider plastically workable temperature region because it has a larger endotherm (J/g) between the glass transition temperature (Tg) and the crystallization temperature (Tx).

However, if the content of each of the chemical constituents departs from the above-described range, an alloy of the type described above cannot be produced by the industrial producing process, and the resulting alloy has a reduced toughness.

If a rare earth element such as La, Ce, Pr, Nd and Md is added as described above, the amorphous layer forming ability of the above-described alloy can be further enhanced.

However, if the content of the rare earth element departs from the above-described range, it is impossible to provide an effect as described above.

If Co is added along with Ni as described above, the amorphous layer forming ability of the above-described alloy can be enhanced, and it is also possible to provide an increased crystallization temperature (Tx) to increase the endotherm and to widen the plastically workable temperature region.

Even if Fe is added, it is believed to provide an increased crystallization temperature (Tx) of the resulting alloy to improve the heat resistance thereof, but the Fe content is set in a range of 0.5 atom % (inclusive) to 3 atom % (inclusive). If the Fe content is less than 0.5 atom %, an effect as described above is not obtained. Any Fe content exceeding 3 atom % will result in a reduced amorphous layer forming ability. It is desirable to add Fe along with Co.

It is another object of the present invention to provide a process for producing a high strength structural member of a high strength amorphous aluminum-based alloy.

To achieve the above object, according to the present invention, there is provided a process for producing a structural member of an amorphous aluminum-based alloy, comprising the steps of forming a green compact from an amorphous aluminum-based alloy having a volume fraction (Vf) of amorphous layer of 50% or more and subjecting the green compact to a hot plastic working, wherein the formation of the green compact is conducted at a temperature in a range lower

than the crystallization temperature (Tx) of the amorphous layer by at least 40°C, thereby setting the density of the green compact at at least 80%.

In forming a high density green compact having a density of 80% or more, it is desirable in consideration of the plasticity of the alloy powder that such formation is conducted in a higher temperature region.

In such a case, if the densification of the green compact is effected by pressing at a temperature in the vicinity of the crystallization temperature of the amorphous layer, the temperature of the alloy powder may be increased due to the friction occurring between particles of the alloy powder to exceed the crystallization temperature (Tx).

In the present invention, however, it is possible to inhibit the crystallization attendant upon the densification of the green compact by setting the temperature region during formation of the green compact in a range lower than crystallization temperature (Tx) by at least 40°C.

In addition, it is possible to lessen the degree of slip between the particles of the alloy powder by subjecting the high density green compact. This ensures that a structural member having a higher volume fraction of the amorphous layer can be produced.

The above and other objects, features and advantages of the invention will become apparent from a reading of the following description of the preferred embodiments, in conjunction with the accompanying drawings.

Fig. 1 is an X-ray diffraction pattern diagram for an amorphous aluminum-based alloy;

Figs. 2 to 9 are thermocurve diagrams of a differential thermal analysis for various amorphous aluminum-based alloys; and

Fig. 10 is a thermocurve diagram of a differential thermal analysis for various green compacts.

Various amorphous aluminum-based alloys which will be described hereinbelow were produced by utilizing a He gas atomizing process. More specifically, the interior of a chamber was depressurized to 2×10^{-3} Torr or less, and an Ar gas was introduced into a chamber. Then, 4 Kg of an alloy was heated to a molten condition by high-frequency heating and then atomized under a He gas pressure of 100 kg f/cm^2 , thereby providing an alloy powder.

I. A first group of amorphous aluminum-based alloys

An amorphous aluminum-based alloy belonging to this first group has a composition comprising

75 atom % \leq Al 90 atom %,

3 atom % \leq Ni 15 atom %, and

3 atom % \leq heavy rare earth element \leq 12 atom %.

Here, at least one element selected from the group consisting of Dy, Er and Gd corresponds to the heavy rare earth element.

The amorphous aluminum-based alloys produced using Dy as the heavy rare earth element include those having a composition comprising

80 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni \leq 13 atom %, and

3 atom % \leq Dy \leq 12 atom %.

Table I illustrates the composition, structure, endotherm and crystallization temperature (T_x) of the amorphous aluminum-based alloys (1) to (9) belonging to the first group and another alloy (10) as a comparative example. In the column of the composition, a indicates that the alloy is of an amorphous structure, and c indicates that the alloy is of a crystalline structure.

Table I

Alloy	Composition	Structure	Endotherm	T_x
No.	(atom %)		(J/g)	(°C)
(1)	Al ₈₅ Ni ₇ Dy ₈	a	7	279.8
(2)	Al ₈₅ Ni ₈ Dy ₇	a	7	271.1
(3)	Al ₈₄ Ni ₈ Dy ₈	a	7	285.9
(4)	Al ₈₄ Ni ₉ Dy ₇	a	8	286.1
(5)	Al ₈₃ Ni ₉ Dy ₈	a	7	301.0
(6)	Al ₈₄ Ni ₁₀ Dy ₆	a	8	286.6
(7)	Al ₈₃ Ni ₁₀ Dy ₇	a	6	299.2
(8)	Al ₈₃ Ni ₁₁ Dy ₆	a	7	298.4
(9)	Al ₈₂ Ni ₁₂ Dy ₆	a	7	312.2
(10)	Al ₉₂ Ni ₄ Dy ₄	c	<1	310.1

Fig. 1 is an X-ray diffraction pattern diagram for the amorphous aluminum-based alloy (4), and in Fig. 1, a halo pattern peculiar to the amorphous alloy can be seen.

Fig. 2 is a thermocurve diagram of a differential thermal analysis for the alloy (4), wherein the glass transition

temperature (tg) is of 259.5°C, and the crystallization temperature (tx) is of 286.1°C. The endotherm between the glass transition temperature (Tg) and the crystallization temperature (Tx) is of 8 J/g.

Fig. 3 is a thermocurve diagram of a differential thermal analysis for the alloy (6), wherein the glass transition temperature (Tg) is of 261.7°C, and the crystallization temperature (Tx) is of 286.6°C. The endotherm between the glass transition temperature (Tg) and the crystallization temperature (Tx) is of 8 J/g.

The Al-Ni-Dy type amorphous aluminum-based alloys (1) to (9) are higher in amorphous layer forming ability and have a volume fraction of an amorphous layer of 100%. In addition, they have endotherms as high as 6 j/g or more, and hence, have a wider plastically workable temperature region. This ensures that in producing members using the above-described alloys (1) to (9) by utilizing a working process such as a hot extruding process, a hot forging process or the like, the workability thereof is satisfactory.

II. A second group of amorphous aluminum-based alloys

An amorphous aluminum-based alloy belonging to the second group has a composition comprising

75 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni \leq 15 atom %,

1 atom % \leq heavy rare earth element \leq 12 atom %, and light rare earth element \leq 8 atom %.

Here, at least one element selected from the group consisting of Dy, Er and Gd corresponds to the heavy rare

earth element. In addition, at least one element selected from the group consisting of La, Ce, Pr, Nd and Md (misch metal) corresponds to the light rare earth element. The addition of such a light rare earth element further enhances the amorphous layer forming ability for the above described alloys.

The amorphous aluminum-based alloys produced using Dy as a heavy rare earth element include those having a composition comprising

80 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni \leq 13 atom %,

1 atom % \leq Dy \leq 12 atom %, and light rare earth element \leq 6 atom %.

The use of the heavy rare earth element and the light rare earth element in combination is an effective technique for enhancing the amorphous layer forming ability. Examples of amounts of incorporation of chemical constituents in this case are as follows:

80 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni \leq 13 atom %,

1 atom % \leq heavy rare earth element \leq 10 atom %, and

1 atom % \leq light rare earth element \leq 6 atom %.

Table II illustrates the composition, structure, endotherm and crystallization temperature (Tx) of the amorphous aluminum-based alloys (11) to (23) belonging to the second group and other alloys (24) to (29) as comparative examples. In the column of the structure, a indicates that the alloy is of an amorphous structure.

Table II

Alloy No.	Composition (atom %)	Structure	Endotherm (J/g)	T _x (°C)
(11)	Al ₈₄ Ni ₁₀ Dy ₃ Md ₃	a	8	284.0
(12)	Al ₈₄ Ni ₁₀ Dy ₂ Md ₄	a	7	284.7
(13)	Al ₈₄ Ni ₁₀ Dy ₁ Md ₅	a	8	280.3
(14)	Al ₈₄ Ni ₁₀ Er ₃ Md ₃	a	8	286.0
(15)	Al ₈₄ Ni ₁₀ Dy ₃ La ₃	a	8	288.3
(16)	Al ₈₂ Ni ₁₀ Dy ₄ La ₄	a	8	327.1
(17)	Al ₈₁ Ni ₁₂ Dy _{3.5} La _{3.5}	a	5	336.1
(18)	Al ₈₄ Ni ₁₀ Dy ₃ Ce ₃	a	7	284.2
(19)	Al ₈₂ Ni ₁₀ Dy ₄ Ce ₄	a	5	320.3
(20)	Al ₈₁ Ni ₁₂ Dy _{3.5} Ce _{3.5}	a	5	324.8
(21)	Al ₈₄ Ni ₁₀ Dy ₃ Pr ₃	a	9	284.4
(22)	Al ₈₂ Ni ₁₀ Dy ₄ Pr ₄	a	5	320.6
(23)	Al ₈₄ Ni ₁₀ Dy ₃ Nd ₃	a	8	286.7
(24)	Al ₈₂ Ni ₁₀ La ₄ Pr ₄	a	1	330.7
(25)	Al ₈₂ Ni ₁₀ La ₄ Ce ₄	a	1	331.1
(26)	Al ₈₂ Ni ₁₀ Ce ₄ Nd ₄	a	< 1	340.7
(27)	Al ₈₆ Ni ₁₀ Md ₄	a	< 1	224.7
(28)	Al ₈₅ Ni ₁₀ Md ₅	a	3	265.7
(29)	Al ₈₄ Ni ₁₀ Md ₆	a	4	285.6

Fig. 4 is a thermocurve diagram of a differential thermal analysis for the alloy (11), wherein the glass transition temperature (T_g) is of 257.1°C, and the crystallization temperature (T_x) is of 284.0°C. The endotherm between the glass transition temperature (T_g) and the crystallization temperature (T_x) is of 8 J/g.

Fig. 5 is a thermocurve diagram of a differential thermal analysis for the alloy (12), wherein the glass transition temperature (T_g) is of 258.9°C , and the crystallization temperature (T_x) is of 284.7°C . The endotherm between the glass transition temperature (T_g) and the crystallization temperature (T_x) is of 7 J/g.

Fig. 6 is a thermocurve diagram of a differential thermal analysis for the alloy (13), wherein the glass transition temperature (T_g) is of 258.3°C , and the crystallization temperature (T_x) is of 280.3°C . The endotherm between the glass transition temperature (T_g) and the crystallization temperature (T_x) is of 8 J/g.

Fig. 7 is a thermocurve diagram of a differential thermal analysis for the alloy (14), wherein the glass transition temperature (T_g) is of 258.9°C , and the crystallization temperature (T_x) is of 286.0°C . The endotherm between the glass transition temperature (T_g) and the crystallization temperature (T_x) is of 8 J/g.

The amorphous aluminum-based alloys (11) to (23) are higher in amorphous layer forming ability and have a volume fraction of an amorphous layer of 100 %. In addition, they also have an endotherm as high as 5 J/g or more and hence, have a wider plastically workable temperature region. This ensures that in producing members using the alloys (11) to (23) by utilizing a working process such as a hot extruding process, a hot forging process and the like, the workability thereof is satisfactory.

If Md is used as a light rare earth element in each of the alloys (11) to (14), the alloys (11) to (14) can be produced at a lower cost because of a lower price of Md, leading to an advantage to provide for mass production.

The alloys (24) to (29) as comparative examples are lower in endotherm and thus, have a narrower plastically workable temperature region, resulting in an inferior workability, because a light rare earth element such as La, Ce, Pr, Nd and Md (La + Ce) is used in combination.

III. A third group of amorphous aluminum-based alloys

An amorphous aluminum-based alloy belonging to the third group has a composition comprising

75 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni + Co and/or Fe \leq 15 atom %, and

3 atom % \leq heavy rare earth element \leq 12 atom %.

Here, at least one element selected from the group consisting of Dy, Er and Gd corresponds to the heavy rare earth element.

The amorphous aluminum-based alloys produced using Ni and Co in combination and using Dy as a heavy rare earth element include those having a composition comprising

80 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni + Co \leq 13 atom %, and

3 atom % \leq Dy \leq 12 atom %.

The amorphous aluminum-based alloys produced using Ni, Co and Fe in combination and using Dy as a heavy rare earth element include those having a composition comprising

80 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni + Co \leq 13 atom %,

0.5 atom % \leq Fe \leq 3 atom %, and

3 atom % \leq Dy \leq 12 atom %.

Table III illustrates the composition, structure, endotherm and crystallization temperature (Tx) of amorphous aluminum-based alloys (30) to (33) belonging to the third group. In the column of the structure, a indicates that the alloy is of an amorphous structure.

Table III

Alloy	Composition	Structure.	Endotherm	Tx
No.	(atom %)		(J/g)	(°C)
(30)	Al ₈₄ Ni ₈ Gd ₆ Co ₂	a	6	286.6
(31)	Al ₈₅ Ni ₅ Dy ₈ Co ₂	a	8	296.8
(32)	Al ₈₄ Ni ₈ Dy ₆ Co ₂	a	5	294.3
(33)	Al ₈₅ Ni ₄ Dy ₈ Co ₂ Fe ₁	a	5	324.3

Fig. 8 is a thermocurve diagram of a differential thermal analysis for the alloy (31), wherein the glass transition temperature (Tg) is of 273.0°C, and the crystallization temperature is of 296.8°C. The endotherm between the glass transition temperature (Tg) and the crystallization temperature (Tx) is of 8 J/g.

The amorphous aluminum-based alloys (30) to (33) are higher in amorphous layer forming ability and have a volume fraction of an amorphous layer of 100 %. In addition, they have an endotherm as high as 5 J/g or more and thus, have a wider plastically workable region. This ensures that in producing members using the alloys (30) to (33) by utilizing a

working process such as a hot extruding process, a hot forging process and the like, the workability thereof is satisfactory.

The improvement in endotherm can be achieved by using Ni and Co in combination, and an effect provided by the use of them in combination is also revealed to increase the crystallization temperature of the Al-Ni-Dy based alloys.

Fe has an effect of increasing the crystallization temperature (Tx) of the above-described alloys to provide an improved heat resistance. As apparent from comparison of the alloy (32) with the alloy (33), the addition of Fe has provided an increase in crystallization temperature (Tx) of the alloy (33) by 30°C from that of the alloy (32).

IV. A fourth group of amorphous aluminum-based alloys

An amorphous aluminum-based alloy belonging to the fourth group has a composition comprising

75 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni + Co and/or Fe \leq 15 atom %,

1 atom % \leq heavy rare earth element \leq 12 atom %, and

light rare earth element \leq 8 atom %.

Here, at least one element selected from the group consisting of Dy, Er and Gd corresponds to the heavy rare earth element.

In addition, at least one element selected from the group consisting of La, Ce, Pr, Nd and Md corresponds to the light rare earth element. The addition of such a light rare earth element ensures that the amorphous layer forming ability for the alloys can be further enhanced.

The amorphous aluminum-based alloys produced using Ni and Co in combination and using Dy as a heavy rare earth element include those having a composition comprising

80 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni + Co \leq 13 atom %,

1 atom % \leq Dy \leq 12 atom %, and

light rare earth element \leq 6 atom %.

The use of such heavy and light rare earth elements in combination is an effective technique for enhancing the amorphous layer forming ability. Optimal examples of amounts of incorporation of chemical constituents in this case are as follows:

80 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni + Co and/or Fe \leq 13 atom %,

1 atom % \leq heavy rare earth element \leq 10 atom %, and

1 atom % \leq light rare earth element \leq 6 atom %.

Table IV illustrates the composition, structure, endotherm and crystallization temperature (Tx) of an amorphous aluminum-based alloy (34) belonging to the fourth group. In the column of the structure, a indicates that the alloy is of an amorphous structure.

Table IV

Alloy	Composition	Structure	Endotherm	Tx
No.	(atom %)		(J/g)	(°C)
(34)	Al ₈₄ Ni ₈ Dy ₃ Md ₃ Co ₂	a	6	300.2

Fig. 9 is a thermocurve diagram of a differential thermal analysis for the alloy (34), wherein the glass transition temperature (Tg) is of 276.1°C, and the crystallization

temperature is of 300.2°C. The endotherm between the glass transition temperature (Tg) and the crystallization temperature (Tx) is of 6 J/g.

The amorphous aluminum-based alloy (34) is higher in amorphous layer forming ability and has a volume fraction of an amorphous layer of 100 %. In addition, it has a high endotherm of 6 J/g and thus, has a wider plastically workable region. This ensures that in producing a member using the alloy (34) by utilizing a working process such as a hot extruding process, a hot forging process and the like, the workability thereof is satisfactory.

The use of the heavy and light rare earth elements in combination has provided good results in Al-(Ni, Co, Fe)-(Dy, Er, Gd)-(La, Ce, Pr, Nd) based alloys and Al-(Ni, Co, Fe)-(Dy, Er, Gd)-Md based alloys.

The other amorphous aluminum-based alloys in accordance with the present invention include those having the following compositions:

80 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni \leq 13 atom %,

0.5 atom % \leq Fe \leq 3 atom %, and

3 atom % \leq Dy \leq 12 atom %,

typical of the alloys of this type being $Al_{84}Ni_9Fe_3Dy_6$:

80 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni \leq 13 atom %,

0.5 atom % \leq Fe \leq 3 atom %,

1 atom % \leq Dy \leq 12 atom %, and

light rare earth element \leq 6 atom %,

the light rare earth element being at least one element selected from the group consisting of La, Ce, Pr, Nd and Md, and typical of the alloys of this type being $Al_{84}Ni_9Fe_1Dy_3La_3$;

80 atom % \leq Al \leq 90 atom %,

3 atom % \leq Ni + Co \leq 13 atom %,

0.5 atom % \leq Fe \leq 3 atom %,

1 atom % \leq Dy \leq 12 atom %, and

light rare earth element \leq 6 atom %,

the light rare earth element being at least one element selected from the group consisting of La, Ce, Pr, Nd and Md, and the alloys of this type including $Al_{84}Ni_{10}Co_2Fe_1Dy_3La_3$.

Description will now be made of the production of a structural member using, by way of example, powder of the alloy (6) having a composition of $Al_{84}Ni_{10}Dy_6$ given in Table 1.

First, a green compact having a diameter of 58 mm and a length of 50 mm was prepared using the above-described powder, then placed into an aluminum (or copper) can having a wall thickness of 10 mm, and subjected to a hot extrusion at an extrusion ratio of 13, thereby providing a bar-like structural member.

Table V illustrates the physical properties of various structural members produced by the above process.

Table V

<u>green compact</u>		<u>Structural member</u>		
Fo. tem.	Den. of P.C.	Ex.Tem.	Den.	Vf of Am.In.
(°C)	(%)	(°C)	(%)	(%)
Room Tem.	90	270	98	\geq 90
220	90	270	98	\geq 90

240	90	270	98	≥ 90
250	90	270	cracking	40
260	90	270	failure to work	15
280	90	270	failure to work	10
Room Tem.	70	270	cracking	40
Room Tem.	80	270	98	≥ 90
220	70	270	cracking	40
220	80	270	98	≥ 90
250	70	270	failure to work	20
250	80	270	cracking	30

Fo.tem. = Forming temperature Den. of P.C. = Density of
 green compact Ex.Tem. = Extruding temperature Den. =
 Density

Vf of Am. In. = Vf of amorphous ingredients

As apparent from Table V, if the formation of the green compact is conducted in a temperature range lower, by 40°C or more, than 286.6°C which is the crystallization temperature of an amorphous alloy powder having a composition of $\text{Al}_{84}\text{Ni}_{10}\text{Dy}_6$, so that the density of the green compact is set at at least 80%, it is possible to provide a structural member with an improved density and to inhibit the reduction in volume fraction (Vf) of amorphous layer to the utmost.

Fig. 10 illustrates a portion of a thermocurve diagram of a differential thermal analysis for each of various green compacts prepared using the amorphous alloy powder ($\text{Al}_{84}\text{Ni}_{10}\text{Dy}_6$) which is in the vicinity of the glass transition temperature

(T_g) and the crystallization temperature (T_x), wherein a line x₁ corresponds to the case where the forming temperature is room temperature, and lines x₂ to x₅ correspond to the cases where the forming temperature is of 220°C, 240°C, 250°C and 260°C, respectively.

In each of the lines x₁ to x₃, a suddenly falling curve portion appears due to an endothermic phenomenon in a temperature range exceeding the glass transition temperature (T_g). This means that the temperature region for plastification of the green compact is wide, leading to a good hot-extrudability of each green compact.

In contrast, with the green compact indicated by the line x₄, the temperature region for plastification thereof is narrower, and with the green compact indicated by the line x₅, there is no temperature region for plastification, resulting in a deteriorated hot-extrudability of each green compact.

CLAIMS

1. A process for producing a structural member of an amorphous aluminum-based alloy, comprising the steps of forming a green compact from an amorphous aluminum-based alloy having a volume fraction (Vf) of amorphous layer of at least 50% and subjecting the green compact to a hot plastic working, wherein the formation of the green compact is conducted at a temperature in a range lower than the crystallization temperature (Tx) of the amorphous layer by at least 40°C, thereby setting the density of the green compact at at least 80%.
2. A process as claimed in Claim 1 including an initial step of forming an amorphous aluminum-based alloy having a composition as defined in any one of claims 3 to 18.
3. A high strength amorphous aluminum-based alloy comprising:
75 atom % (inclusive) to 90 atom % (inclusive) of Al;
3 atom % (inclusive) to 15 atom % (inclusive) of Ni; and
3 atom % (inclusive) to 12 atom % (inclusive) of at least one element selected from a group consisting of Dy, Er and Gd,
said alloy having an amorphous layer volume fraction (Vf) of at least 50%.
4. A high strength amorphous aluminum-based alloy comprising:
75 atom % (inclusive) to 90 atom % (inclusive) of Al;
3 atom % (inclusive) to 15 atom % (inclusive) of Ni;

1 atom % (inclusive) to 12 atom % (inclusive) of at least one element selected from a group consisting of Dy, Er and Gd; and
0 atom % (inclusive) to 8 atom % (inclusive) of at least one element selected from a group consisting of La, Ce, Pr, Nd and Md (misch metal),
said alloy having an amorphous layer volume fraction (Vf) of at least 50%.

5. A high strength amorphous aluminum-based alloy comprising:

75 atom % (inclusive) to 90 atom % (inclusive) of Al;
3 atom % (inclusive) to 15 atom % (inclusive) of Ni plus at least one element selected from Co and Fe; and
3 atom % (inclusive) to 12 atom % (inclusive) of at least one element selected from a group consisting of Dy, Er and Gd,
said alloy having an amorphous layer volume fraction (Vf) of at least 50%.

6. A high strength amorphous aluminum-based alloy comprising:

75 atom % (inclusive) to 90 atom % (inclusive) of Al;
3 atom % (inclusive) to 15 atom % (inclusive) of Ni plus at least one element selected from Co and Fe;
1 atom % (inclusive) to 12 atom % (inclusive) of at least one element selected from a group consisting of Dy, Er and Gd; and
0 atom % (inclusive) to 8 atom % (inclusive) of at least one element selected from a group consisting of La, Ce, Pr, Nd and Md (misch metal),
said alloy having an amorphous layer volume fraction (Vf) of at least 50%.

7. A high strength amorphous aluminum-based alloy as claimed in Claim 3 comprising:

80 atom % (inclusive) to 90 atom % (inclusive) of Al;

3 atom % (inclusive) to 13 atom % (inclusive) of Ni; and

3 atom % (inclusive) to 12 atom % (inclusive) of Dy.

8. A high strength amorphous aluminum-based alloy as claimed in Claim 4 comprising:

75 atom % (inclusive) to 90 atom % (inclusive) of Al;

3 atom % (inclusive) to 15 atom % (inclusive) of Ni;

1 atom % (inclusive) to 12 atom % (inclusive) of at least one element selected from a group consisting of Dy, Er and Gd; and

1 atom % (inclusive) to 8 atom % (inclusive) of at least one element selected from a group consisting of La, Ce, Pr, Nd and Md (misch metal).

9. A high strength amorphous aluminum-based alloy as claimed in Claim 8 comprising:

80 atom % (inclusive) to 90 atom % (inclusive) of Al;

3 atom % (inclusive) to 13 atom % (inclusive) of Ni;

1 atom % (inclusive) to 12 atom % (inclusive) of Dy; and

1 atom % (inclusive) to 6 atom % (inclusive) of at least one element selected from a group consisting of La, Ce, Pr, Nd and Md (misch metal).

10. A high strength amorphous aluminum-based alloy as claimed in Claim 8 comprising:

80 atom % (inclusive) to 90 atom % (inclusive) of

Al;

3 atom % (inclusive) to 13 atom % (inclusive) of Ni;

1 atom % (inclusive) to 10 atom % (inclusive) of at least one element selected from a group consisting of Dy, Er and Gd; and

1 atom % (inclusive) to 6 atom % (inclusive) of at least one element selected from a group consisting of La, Ce, Pr, Nd and Md (misch metal).

11. A high strength amorphous aluminum-based alloy as claimed in Claim 5 comprising:

80 atom % (inclusive) to 90 atom % (inclusive) of Al;

3 atom % (inclusive) to 13 atom % (inclusive) of Ni plus Co; and

3 atom % (inclusive) to 12 atom % (inclusive) of Dy.

12. A high strength amorphous aluminum-based alloy comprising:

80 atom % (inclusive) to 90 atom % (inclusive) of Al;

3 atom % (inclusive) to 13 atom % (inclusive) of Ni;

0.5 atom % (inclusive) to 3 atom % (inclusive) of Fe; and

3 atom % (inclusive) to 12 atom % (inclusive) of Dy,

said alloy having an amorphous layer volume fraction (Vf) of at least 50%.

13. A high strength amorphous aluminum-based alloy comprising:

80 atom % (inclusive) to 90 atom % (inclusive) of Al;

3 atom % (inclusive) to 13 atom % (inclusive) of Ni

plus Co;
0.5 atom % (inclusive) to 3 atom % (inclusive) of Fe; and
3 atom % (inclusive) to 12 atom % (inclusive) of Dy,
said alloy having an amorphous layer volume fraction (Vf) of at least 50%.

14. A high strength amorphous aluminum-based alloy as claimed in Claim 6 comprising:

75 atom % (inclusive) to 90 atom % (inclusive) of Al;
3 atom % (inclusive) to 15 atom % (inclusive) of Ni plus at least one element selected from Co and Fe;
1 atom % (inclusive) to 12 atom % (inclusive) of at least one element selected from a group consisting of Dy, Er and Gd; and
1 atom % (inclusive) to 8 atom % (inclusive) of at least one element selected from a group consisting of La, Ce, Pr, Nd and Md (misch metal).

15. A high strength amorphous aluminum-based alloy as claimed in Claim 14 comprising:

80 atom % (inclusive) to 90 atom % (inclusive) of Al;
3 atom % (inclusive) to 13 atom % (inclusive) of Ni plus Co;
1 atom % (inclusive) to 12 atom % (inclusive) of Dy; and
1 atom % (inclusive) to 6 atom % (inclusive) of at least one element selected from a group consisting of La, Ce, Pr, Nd and Md (misch metal).

16. A high strength amorphous aluminum-based alloy comprising:

80 atom % (inclusive) to 90 atom % (inclusive) of Al;

3 atom % (inclusive) to 13 atom % (inclusive) of Ni;
0.5 atom % (inclusive) to 3 atom % (inclusive) of Fe;
1 atom % (inclusive) to 12 atom % (inclusive) of Dy; and
1 atom % (inclusive) to 6 atom % (inclusive) of at least one element selected from a group consisting of La, Ce, Pr, Nd and Md (misch metal),
said alloy having an amorphous layer volume fraction (Vf) of at least 50%.

17. A high strength amorphous aluminum-based alloy comprising:

80 atom % (inclusive) to 90 atom % (inclusive) of Al;
3 atom % (inclusive) to 13 atom % (inclusive) of Ni plus Co;
0.5 atom % (inclusive) to 3 atom % (inclusive) of Fe;
1 atom % (inclusive) to 12 atom % (inclusive) of Dy; and
1 atom % (inclusive) to 6 atom % (inclusive) of at least one element selected from a group consisting of La, Ce, Pr, Nd and Md (misch metal),
said alloy having an amorphous layer volume fraction (Vf) of at least 50%.

18. A high strength amorphous aluminum-based alloy as claimed in Claim 14 comprising:

80 atom % (inclusive) to 90 atom % (inclusive) of Al;
3 atom % (inclusive) to 13 atom % (inclusive) of Ni plus at least one element selected from Co and Fe;
1 atom % (inclusive) to 10 atom % (inclusive) of at least one element selected from a group consisting of Dy, Er and Gd; and

1 atom % (inclusive) to 6 atom % (inclusive) of at least one element selected from a group consisting of La, Ce, Pr, Nd and Md (misch metal).

19. Use of a composition as claimed in any one of Claims 3 to 18 in the manufacture of a structural member.

20. A composition as claimed in any one of Claims 3 to 18 substantially as herein described.

21. A process as claimed in Claim 1 or Claim 2 substantially as herein described.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
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27

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Relevant Technical Fields

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(ii) Int Cl (Ed.5) C22C 45/00, B22F 3/00

Databases (see below)

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASES: WPI, CLAIMS

Search Examiner
A R MARTIN

Date of completion of Search
18 FEBRUARY 1994

Documents considered relevant following a search in respect of Claims :-
Claims 1 and 2

Categories of documents

- X: Document indicating lack of novelty or of inventive step.
- Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.
- A: Document indicating technological background and/or state of the art.
- P: Document published on or after the declared priority date but before the filing date of the present application.
- E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.
- &: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	US 5145503	(HONA) see examples	Claim 1 at least
A	US 4851193	(US AIR FORCE) see column 1 lines 30-65	Claim 1 at least

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).